Saskatchewan
Environment and
Public Safety
Mines Pollution
Control Branch

Radon Survey III
Continuous Monitoring in Ten Saskatchewan Homes

April, 1989

RADON SURVEY III

CONTINUOUS MONITORING IN TEN SASKATCHEWAN HOMES

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A. INTRODUCTION

1. General

Radon is a naturally occurring, radioactive gas formed by the decay of radium in rocks and soils. Radon works its way through soil and in the outdoor atmosphere is diluted to low concentrations. Radon enters subgrade structures through concrete cracks, vents, floor drains, sumps and joints. Radon and its decay products can build-up in enclosed areas.

A relationship between high levels of radon and radon daughters in mine atmospheres and an increased risk of developing lung cancer has been determined. The degree of risk depends on the level of radon, the length of time exposed, personal characteristics and the degree of exposure to other carcinogens.

The level of radon in a home depends on many factors including the concentration of radium in the surrounding soil, construction of the house, type and condition of basement, and the amount of ventilation. Radon levels are extremely variable over time in homes.[1]

2. Past Programs

The Technical Services Section of the Mines Pollution Control Branch of Saskatchewan Environment and Public Safety is responsible for the development of programs to ensure protection of the public from naturally occurring radiation hazards. These hazards are generally associated with the presence of radon in buildings. Saskatchewan Environment has participated in and conducted research programs and radon surveys. During the period 1975 to 1981, Uranium City was the site of practical research into radon measurement and radon reduction techniques in homes. The work done in Uranium City provided a good base for further research work conducted in Ontario and in the USA.

In the early 1980's Saskatchewan Environment recognized that other areas of Saskatchewan could have higher than normal levels of radon gas in the homes. The Department embarked on radon surveys in Northern Saskatchewan and in the far southern part of the province. In the north, higher than normal levels of uranium occur in the precambrian shield rocks. A relationship was found between equivalent uranium levels determined by airborne gamma ray surveys and radon daughter levels in homes[2]. In the south, the surveys concentrated on areas where the Ravenscrag formation is near surface. The coal-bearing Ravenscrag formation has higher than normal levels of uranium. The report "Radon Surveys in Saskatchewan"[2], discusses the results of the surveys and recommends that a more detailed survey be conducted in 10 homes in Southern Saskatchewan.

In addition to the radon in homes surveys in northern and southern Saskatchewan, Health and Welfare Canada conducted surveys in Saskatoon and Regina. In all of the above noted surveys, radon progeny levels were determined using short term grab samples in the lowest level of the home. The surveys were conducted at various times of the year.

The results of the previous surveys are summarized in Table 1.

Table 1 - Summary of Saskatchewan Radon Surveys

Location	Number of Homes Surveyed	Number of Homes Above the Canadian Action Level	% Above The Canadian Action Level
Northern Saskatchewan	313	5	1.6
Southern Saskatchewan	613	10	1.6
Regina	961	3	0.3
Saskatoon	770	0	0

As expected, the levels of radon in homes in northern and southern Saskatchewan were higher than the Canadian average[3], but the percentage of homes with levels above the Canadian Action Level (800 Bq/m^3) was low.

> Note: At a meeting in December, 1988, the Committee of Deputy Ministers of Health supported the following recommendation: "that remedial measures be taken where the level of radon in a home is found to exceed 800 Bq/m^3 as the annual average concentration. Because there is some risk at any level of radon exposure, home owners may wish to reduce levels of radon as low as practicable."

3. Objective

The objective of this survey was to obtain more reliable radon level data on selected homes included in the original south survey. Homes were selected to investigate variations seasonally

and spatially within the dwellings, and to follow-up on the reliability of the original survey in Southern Saskatchewan. The selected homes were those that had radon daughter levels above 0.10 WL in the 1981 survey.

B. PROCEDURES

1. Initial Set-up

The occupants of ten previously selected homes in Southern Saskatchewan were contacted by mail to advise of the Department's desire to conduct the survey. In August, 1987 the residences were visited and inspected. Permission from the homeowners to begin the survey was obtained and information on the homes was collected:

- location,
- age of house,
- type of basement construction:
  - wood, concrete
  - walls, floor
  - condition,
  - sumps, joints, drains,
- use of basement,
- heating,
- water supply,
- construction of house,
- ventilation.

Homes surveyed were located in seven communities located in south central and south west Saskatchewan.

2. Equipment

Because of its ability to provide integrated average measurements of radon over periods of one month to one year, the Terradex Type SF alpha-track detector was selected for use in the survey. The use of alpha-track detectors to measure radon gas levels (as opposed to radon progeny measurements), are totally accepted in other jurisdictions to provide a firm basis for exposure risk estimates [4], [5], [6]

3. Locations, Seasons

The survey was designed to investigate seasonal average levels in various parts of homes (ie. basements, ground floor, and upper levels). As well, the potential contribution from water was investigated by monitoring in the most used bathroom. All of the bathrooms monitored were on above-ground levels of the homes.

The seasonal monitoring was split up as follows:

- Autumn - late August to late November, 1987
- Winter - late November, 1987 to late February, 1988
- Spring - late February to late May, 1988
- Summer - late May to late August, 1988

Location selection for initial placement of the alpha-track detectors was made during the residence visits in August, 1987. Subsequent exchanges of the detectors were made by mail with the assistance of the home occupants.

The detectors were sealed in aluminum foil packages for prompt shipment to the laboratory in Glenwood, Illinois for analysis and reading.

C. RESULTS/DISCUSSION

1. General

Information regarding the house construction, basement, water supply, etc. is shown in Appendix I, Table I. There are differences that could affect radon concentrations.

All water supplies except one are well supplies, four of which are private wells. There are large differences in the construction of the basements, ranging from dirt cellars to competent wood and concrete.

The detailed radon survey data are shown in Appendix II. Some data points were excluded because the results were obviously extraneous, when compared to other measurements in the same home. The detectors used in the Fall, Winter and Spring surveys were slightly older than those used in the summer survey. Some of the protective foil pouches could possibly have had leaks prior to opening, causing excessively high values. One winter basement value (home 8) was excessively low when compared to fall and spring values and was therefore excluded.

Table 2 shows annual average radon levels in the three locations (basement, bathroom, living area) in the ten homes.

Table 2 - Annual Average Radon Levels (Bq/m^3)

Home	Basement	Bathroom	Living Area	Means
1	400	141	244	262
2	411	230	293	311
3	652	430	341	474
4	1378	1337	1000	1238
5	207	189	52	149
6	1007	381	478	622
7	674	126	141	314
8	385	22	44	151
9	322	285	204	270
10	930	178	144	417
Arithmetic Means	685	332	306	441
Geometric Means	548	212	200	345

Arithmetic means are 22% to 44% higher than geometric means reflecting the significant variation in the radon levels in the ten homes over the seasons.

2. Sampling Time Variation

The radon (progeny) measurements from the 1981 survey are shown in Table IIF (Appendix II). Linear regression analyses were used to compare the 1981 survey results to 1987/88 annual average radon levels in the basement, bathroom and living areas. There was no correlation (r^2 ranges from 0.003 to 0.05) between the 1981 short-term radon progeny measurements and the annual average radon levels measured in 1987/88.

The variability of short-term tests have been reported by other researchers. Castren [7] reports fifteen fold variations in hourly mean radon concentrations over a three week period. Ronca-Battista [4] concluded that "total measurement uncertainty decreases with increasing sampling time". In the United Kingdom, the National Radiation Protection Board [8] recommends that radon tests in homes be conducted using three month integrated measurements with alpha-track detectors.

3. Basements vs. Upper Living Areas

Table 3 shows the annual average radon levels (geometric means) in the different locations within the homes surveyed.

Figure 1 shows the geometric means of radon levels in the ten homes in the basements, upper living area and bathrooms. The Figure shows the much higher radon levels in the basements compared to the upper living areas and bathrooms.

Table 3 - Annual Average Radon Levels - Ten Homes

(Geometric Means)
(Bq/m^3)

	Fall	Winter	Spring	Summer	Mean
Basement	693	559	678	293	548
Bathroom	159	348	200	70	212
Living Area	207	296	233	67	200
Mean	284	386	316	111	285

Basement radon levels are on average 2.66 times higher than radon levels on the upper floor. This agrees well with the finding of Cohen [1] who found basements averaged 2.5 times higher radon levels than upper floors.

4. Seasonal Variation

Table 3 above shows seasonal variations of geometric mean levels in the ten homes. The data are also shown graphically in Figure 2 and Figure 3.

Winter, Spring, and Fall measurements average about 3.4 times, 2.8 times, and 2.6 times respectively higher than average Summer measurements. Cohen [1] found that Winter and Spring-Fall levels were about 60% and 40% higher than Summer values. The smaller Winter to Summer variation in Cohen's data is likely due to the smaller variation in extreme temperatures in the USA compared to Saskatchewan. Hess [10] found that Winter to Summer ratios ranged from 0.5 - 7 and averaged 1.8. Cohen [1] found that open windows reduce radon levels by a factor of 2.5.

It was unexpectedly found that average levels of radon in the basements in the Winter were less than average levels in the Fall and Spring. This peculiarity could be caused by increased air

Figure 1 - RADON LEVELS - TEN HOMES
GEOMETRIC MEANS

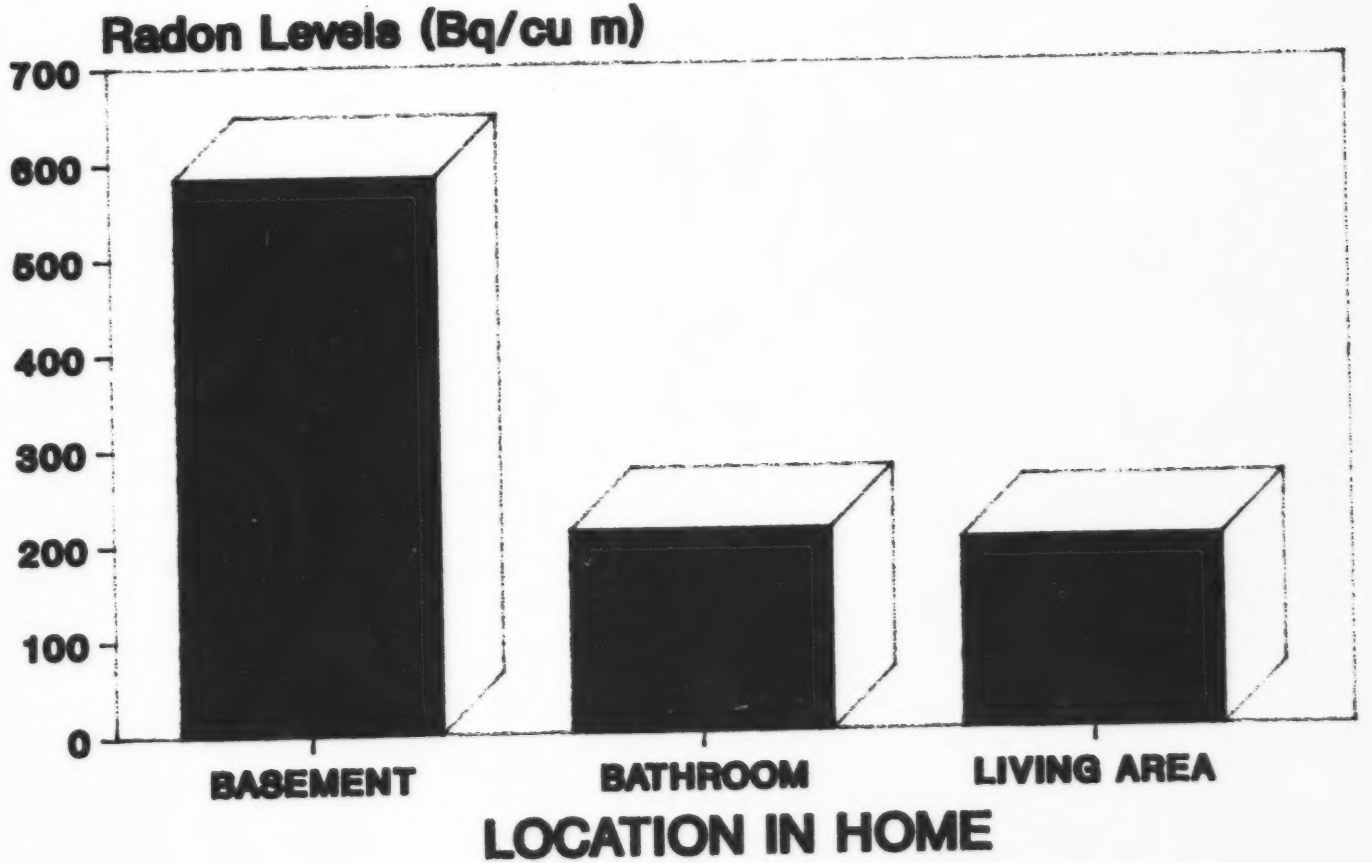


Figure 2 - RADON LEVELS - SEASONAL
GEOMETRIC MEANS - TEN HOMES

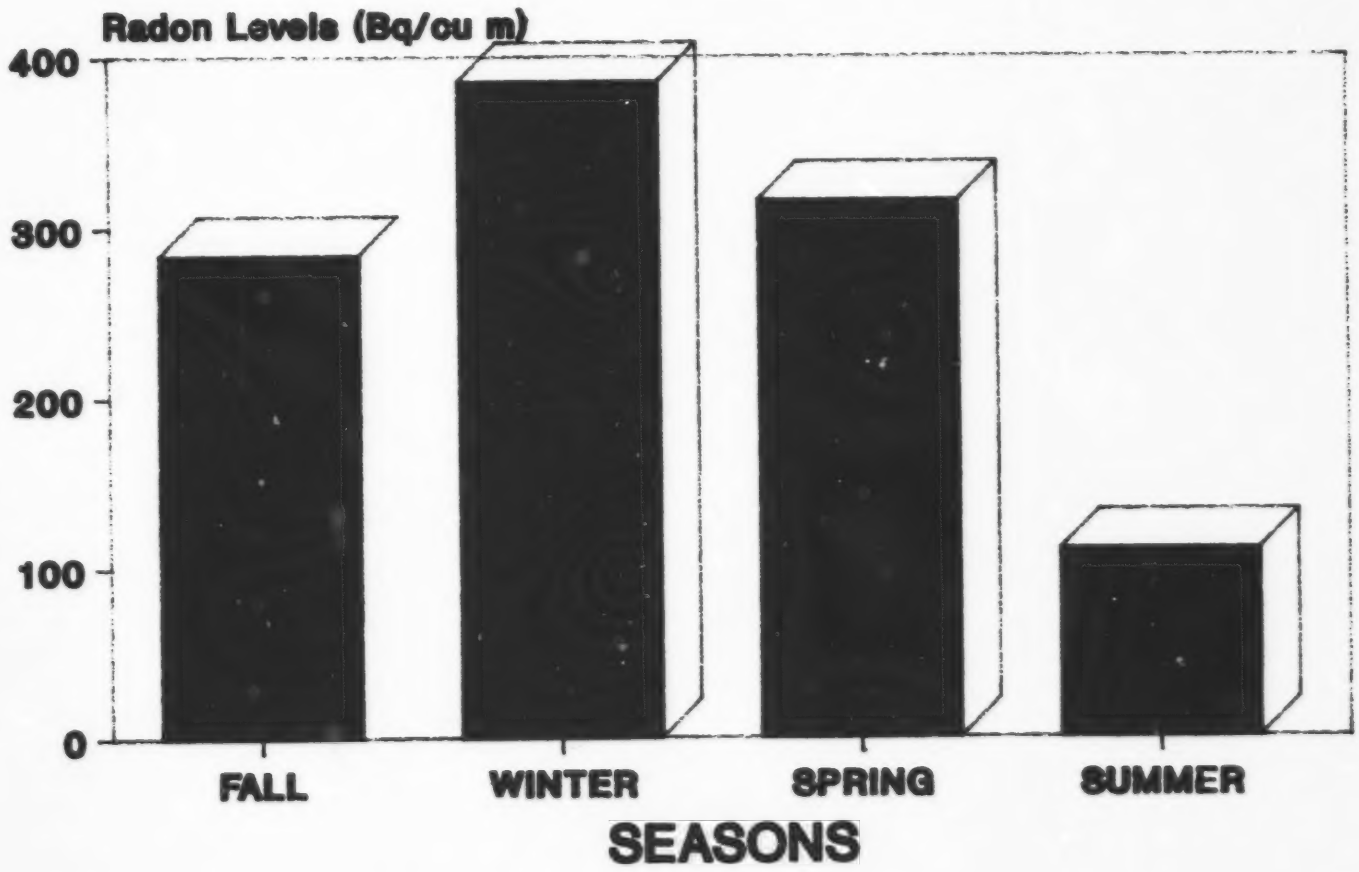
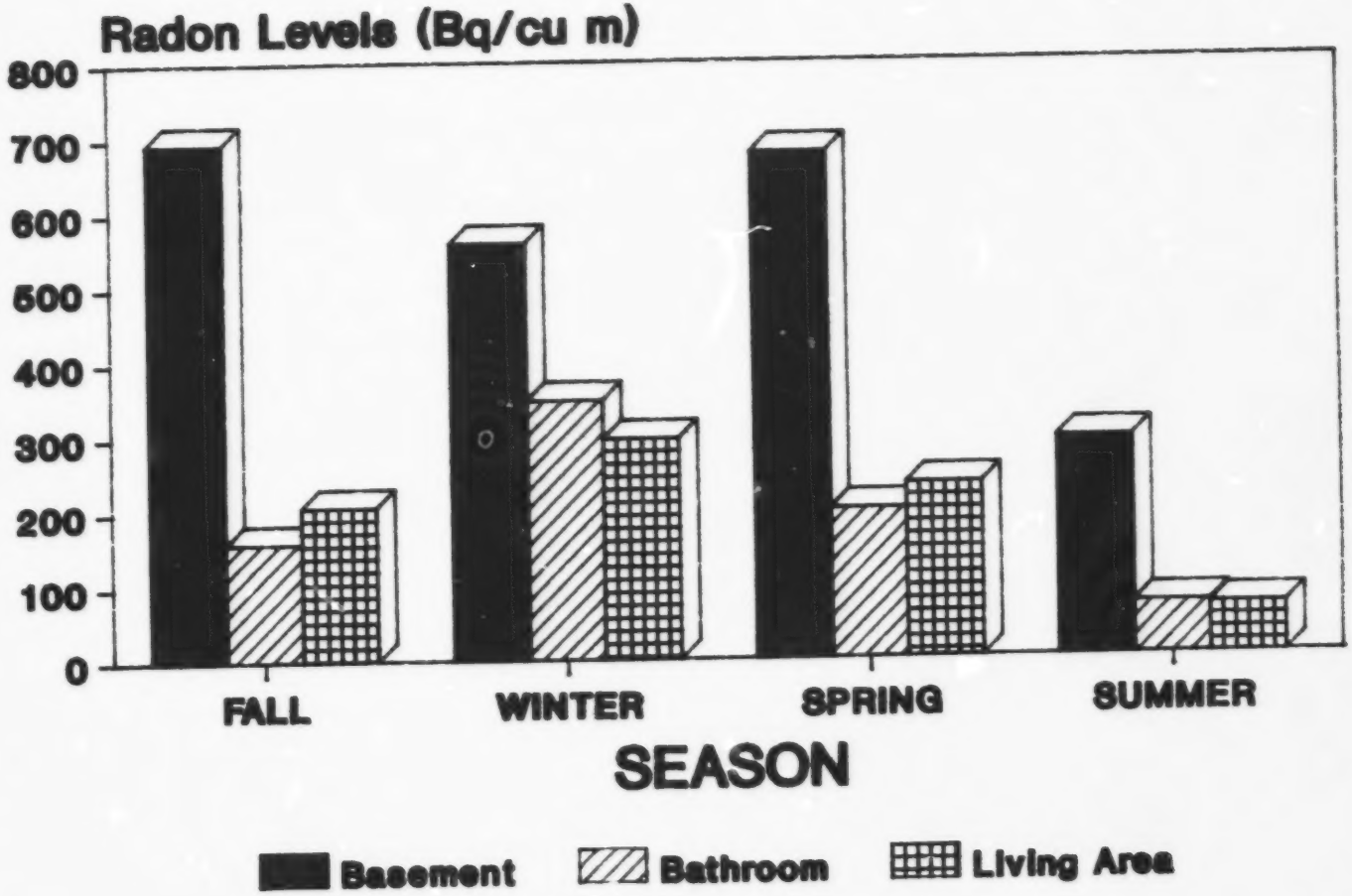


FIGURE 3 - RADON LEVELS - SEASONAL



Note: Geometric Means - Ten Homes

circulation between the basement and upper levels in the Winter, due to increased durations of forced air furnace operation in the Winter. Levels of radon on the ground floor were higher in Winter than the Fall and Spring levels.

Fall and Spring basement radon levels were respectively about 1.26 and 1.24 times the mean basement value, both about 2.4 times the mean annual household value (annual mean of all locations in the home) and 3.4 and 3.3 times the mean living area radon levels (based on geometric means).

Fall living area levels averaged 73% of mean annual household levels and were nearly equal to mean annual living area levels. Winter living area measurements averaged very close to mean household levels and were approximately 1.4 times mean annual living area levels. Spring living area measurements averaged 82% of the mean annual household level and were about 1.1 times the mean annual living area levels. Summer average levels in the basement were approximately 1.4 times the mean annual living area levels.

5. Water

Ground water can have significantly high levels of radon. Surface waters have low radon levels because of continuous exposure to the atmosphere. Nero [9] reports values as high as 101,000 pCi/L (3.7 MBq/m^3) and states that "Rn-222 in water can quickly transfer to air, with efficiencies of 30% to 90% depending on water use." Nero [9] also states that a radon concentration of 10,000 pCi/L in water can raise the average indoor Rn-222 levels by about 1 pCi/L. High levels of radon in drinking water do not cause health risks through drinking the water but can contribute to radon in the atmosphere of a home.

All of the home water supplies except one are ground water supplies (see Table I). Four of the homes use private wells and five are on community well water supplies.

The one home with a surface water supply had an unexplained higher average radon level in the bathroom than in the living area (178 Bq/m^3 compared to 144 Bq/m^3). The average radon level in the bathrooms of homes on community ground water supplies was 222 Bq/m^3 and in the living areas was 225 Bq/m^3. Two of the homes with private well water supplies had higher average radon levels in the bathrooms when compared to levels in the living areas. Two of the homes with private well water supplies had higher average radon levels in the living areas compared to levels in the bathrooms. An alpha-track detector (type SW) was used to measure radon levels in the ground water supply for the home with the highest level found in the bathroom. The level measured in the water was 748 pCi/L (28 Bq/L), which theoretically would contribute less than 1

pCi/L (37 Bq/m^3) to the indoor air concentration.

6. Basement Construction

All of the homes surveyed have basements or cellars. Four homes have concrete basements, two have wood basements, and four have at least one wall or floor of exposed soil. The homes with exposed walls or floor (cellars) had significantly higher levels of radon in both the below ground rooms and the ground floors compared to those homes with competent concrete or wood basements (see Table 4 below).

Table 4 - MEAN ANNUAL RADON CONCENTRATIONS According to Basement Construction (Bq/m^3)

	Basement Type	
	Concrete/Wood	Soil/Cellar
Basement	396	997
Living Area	196	441

D. CONCLUSIONS

1. There are significant variations of radon levels in a home, both spatially within the home and over time.

2. Short term tests in basements should not be used for radon exposure risk assessments. Short term tests are best recognized only as screening type measurements.

3. Accurate exposure assessments should be done using annual average measurements in the most used living areas of the home. Reasonably good assessments can be obtained by conducting three month tests in the main living areas in the Spring or Fall.

4. Basement radon levels are significantly higher than levels on the ground floor (about 2.5 x).

5. Winter levels on the ground floor averaged 1.4 times the mean annual ground floor levels and 4.4 times the summer ground floor level.

6. Ground water was not a significant contributor to indoor radon levels in the homes tested.

7. Radon levels in basements and ground floors of homes with exposed earth walls or floors are likely to be higher than houses with competent wood or concrete basements.

REFERENCES

1. Cohen, B.L. and Gromicko, Nickifor, "Variation of Radon Levels in U.S. Homes with Various Factors", Journal of the Air Pollution Control Association, February, 1988.

2. "Radon Surveys in Saskatchewan", March, 1985 Saskatchewan Environment and Public Safety.

3. Letourneau, E.G., Mao.Y., McGregor, R.G., Semenciw, R., Smith, M.H., and Wigle D.T. "Lung Cancer Mortality and Indoor Radon Concentrations in 18 Canadian Cities", Proceedings of the 16th Midyear Topical Symposium, Health and Physics Society, Albuquerque, N.M., Jan, 1983.

4. Ronca-Battista, M., and Magno, P., "A Comparison of the Variability of Different Techniques and Sampling Periods for Measuring Rn222 and It's Decay Products." Health Physics, Vol. 55, No. 5, November, 1988.

5. James, A.C., National Radiation Protection Board, UK, "Radon in Buildings, Keynote address, Canadian Radiation Protection Association 8th Annual Conference May, 1987.

6. James, A.C., "A Reconsideration of Cells at Risk and Other Key Factors in Radon Daughter Dosimetry,", presented at the 191st Meeting of the American Chemical Society, New York, April 13 - 16, 1986.

7. Castren, O., Makelainen, I., Wingvist, K., and Voutilainen, A., "Indoor Radon Measurements in Finland: A Status Report," presented at the 191st Meeting of the American Chemical Society, New York, April 13 - 16, 1986.

8. Department of the Environment, United Kingdom, "The Householders' Guide to Radon", June, 1988, published by the U.K. Central Office of Information.

9. Hess, C.T., Fleischer, R.L., and Turner, L.G., "Field and Laboratory Tests of Etched Track Detectors for Rn-222: Summer-vs-Winter Variations and Tightness Effects in Maine Houses"., Health Physics, Vol. 49, No. 1, July, 1985.

10. Nero, A.V., "Airborne Radionuclides and Radiation in Buildings: A Review.", Health Physics, Vol. 45, No. 2, August, 1983.

APPENDIX I

CHARACTERISTICS OF HOMES SURVEYED

TABLE I HOME CHARACTERISTICS

HOME		BASEMENT		SUMPS, DRAINS	HEATING	WATER SUPPLY
No.	TYPE	CONSTRUCTION	USE			
1	Bungalow	Wood Walls Concrete Floor	Seldom	Weeping Tile to sump	Electric	Community Well
2	Bungalow Normal Insulation	Concrete	Moderate Rumpus Room	Weeping Tile open sump	Electric Forced Air	Community Well
3	Bungalow Normal Insulation	Wood	Seldom	------	Electric	Community Well
4	Older Home Normal Insulation	Concrete One exposed dirt wall	Seldom	None	Forced Air	Private Well
5	1 1/2 Storey Older Home	Concrete, poor cond. Exposed earth	Seldom	None	Oil Forced Air	Private Well
6	Bungalow Normal Insulation	Concrete Walls Dirt Floor	Seldom	Sump Pump	Forced Air Gas	Private Well
7	Bungalow - Home only used in Summer	Dirt Cellar	Very Seldom	-----	-----	Private Well
8	1 1/2 Storey Older Home	Dirt Cellar	Preserves, Seldom	None	Forced Air	Community Well
9	2 Storey Older Home	Concrete, poor condition	Seldom	Cistern	Forced Air	Community Well
10	Bungalow Normal Insulation	Concrete, good condition	Moderate - Bedroom	Sump Floor Drain	Forced Air	Community Surface Water

APPENDIX II

RADON SURVEY DATA
(in pCi/L and Bq/m^3)

TABLE II A RADON LEVELS IN BASEMENT (pCi/L)

HOME	FALL	WINTER	SPRING	SUMMER	MEAN
1	26.8	7.1	4.3	4.8	10.8
2	15.8	9.0	-	8.5	11.1
3	26.9	22.8	9.0	11.7	17.6
4	52.4	50.9	38.8	6.5	37.2
5	6.6	4.3	-	5.9	5.6
6	24.9	26.6	39.0	18.4	27.2
7	16.5	18.9	29.3	7.9	18.2
8	14.1	-	14.9	2.3	10.4
9	9.2	9.7	-	7.1	8.7
10	25.1	25.6	26.9	22.6	25.1
ARITHMETIC MEANS	21.83	19.43	23.17	9.57	18.50
GEOMETRIC MEANS	18.7	15.1	18.3	7.9	14.8

TABLE II B RADON LEVELS IN BASEMENT (Bq/ cu. m)

HOME	FALL	WINTER	SPRING	SUMMER	MEAN
1	993	263	159	178	398
2	585	333	-	315	411
3	996	844	333	433	652
4	1941	1885	1437	241	1376
5	244	159	-	219	207
6	922	985	1444	681	1008
7	611	700	1085	293	672
8	522	-	552	85	386
9	341	359	-	263	321
10	930	948	996	837	928
ARITHMETIC MEANS	809	720	858	354	685
GEOMETRIC MEANS	693	558	678	294	546

TABLE II C RADON LEVELS IN BATHROOM (pCi/L)

HOME	FALL	WINTER	SPRING	SUMMER	MEAN
1	3.0	5.2	3.8	3.1	3.8
2	5.0	9.0	8.4	2.3	6.2
3	16.7	14.1	11.1	4.6	11.6
4	48.8	45.0	46.6	4.0	36.1
5	2.5	15.4	1.4	0.9	5.1
6	9.2	17.1	13.4	1.5	10.3
7	3.4	4.3	4.0	1.9	3.4
8	0.1	1.4	0.6	0.3	0.6
9	3.6	15.2	7.7	4.4	7.7
10	6.7	7.5	3.7	1.4	4.8
ARITHMETIC MEANS	9.90	13.42	10.07	2.44	8.96
GEOMETRIC MEANS	4.3	9.4	5.4	1.9	5.7

TABLE II D RADON LEVELS IN BATHROOM (Bq/cu. m)

HOME	FALL	WINTER	SPRING	SUMMER	MEAN
1	111	193	141	115	140
2	185	333	311	85	229
3	619	522	411	170	431
4	1807	1667	1726	148	1337
5	93	570	52	33	187
6	341	633	496	56	381
7	126	159	148	70	126
8	4	52	22	11	22
9	133	563	285	163	286
10	248	278	137	52	179
ARITHMETIC MEANS	367	497	373	90	332
GEOMETRIC MEANS	160	348	200	70	213

TABLE II E RADON LEVELS IN LIVING AREAS (pCi/L)

HOME	FALL	WINTER	SPRING	SUMMER	MEAN
1	3.8	11.5	7.0	3.9	6.6
2	12.7	10.8	5.1	2.9	7.9
3	14.9	9.6	8.4	4.0	9.2
4	26.7	45.5	33.5	2.2	27.0
5	2.0	1.6	-	0.7	1.4
6	11.3	28.8	10.0	1.3	12.9
7	2.6	8.1	2.8	1.8	3.8
8	1.6	1.1	1.4	0.6	1.2
9	3.8	7.5	6.4	4.1	5.5
10	4.3	6.7	-	0.8	3.9
ARITHMETIC MEANS	8.37	13.12	9.33	2.23	8.26
GEOMETRIC MEANS	5.6	8.0	6.3	1.8	5.4

TABLE II F RADON LEVELS IN LIVING AREAS (Bq/cu.m)

HOME	FALL	WINTER	SPRING	SUMMER	MEAN
1	141	426	259	144	242.6
2	470	400	189	107	291.7
3	552	356	311	148	341.7
4	989	1685	1241	81	999.1
5	74	59	-	26	53.1
6	419	1067	370	48	475.9
7	96	300	104	67	141.7
8	59	41	52	22	43.5
9	141	278	237	152	201.9
10	159	248	-	30	145.7
ARITMETIC MEANS	310	486	345	83	306
GEOMETRIC MEANS	207	298	234	66	202

TABLE II G ANNUAL AVERAGE RADON LEVELS
TEN HOMES (pCi/L)

HOME	BASEMENT	BATHROOM	LIVING AREA	MEANS 87/88 SURVEY	*MEASURED LEVEL 1981
1	10.8	3.8	6.6	7.07	24.4
2	11.1	6.2	7.9	8.40	22.4
3	17.6	11.6	9.2	12.80	37
4	37.2	36.1	27	33.43	23.2
5	5.6	5.1	1.4	4.03	20
6	27.2	10.3	12.9	16.80	36
7	18.2	3.4	3.8	8.47	38
8	10.4	0.6	1.2	4.07	27.2
9	8.7	7.7	5.5	7.30	21.6
10	25.1	4.8	3.9	11.27	20.8
ARITHMETIC MEANS	18.5	8.96	8.26	11.91	
GEOMETRIC MEANS	14.8	5.7	5.4	9.3	

* Note: See Reference (2)
- these levels were calculated from WL measurements (Kuznetz) assuming an equilibrium factor of 0.5.